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Effects of hormonal and magneto-priming on seed germination traits of sorghum (*Sorghum bicolor* L. Moench)

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Sorghum (*Sorghum bicolor* L. Moench) seeds were tested to discover how different priming techniques affected their germination rates, a pot experiment was conducted by the combination procedures for seed priming with magnetic fields (magneto-priming) and hormonal priming seed with gibberellic acid (AG_3) or ascorbic acid (AsA). Final germination percentage (FGB), mean germination time (MGT), germination rate index (GRI), coefficient of the velocity of germination (CVG), mean daily germination (MDG), peak value (PV), and germination value (GV) are all included as germination metrics. Among the two durations of exposure time to magneto-priming used, the significantly highest FGB, GRI, CVG, MDG, PV and GV were reported in the primed with the time duration 1 h (MP_2), significantly lowest MGT for MGT in days. Whereas among the two hormonal primings used, GA_3 recorded the highest increases upon the unprimed seeds for FGB, GRI, CVG, MDG, PV, and GV, in addition, significantly lowest MGT for MGT in days. However, when magnetic seed is combined shows the highest increase rates compared to the control treatment for time exposure for 1 h (MP_2) with GA_3 or AsA in all studied traits, in addition to the lowest rates decrease in MGT. Overall, the findings imply that seed priming by magnetic field and hormone priming via GA3 or AsA may be promising and practical priming techniques because of their favorable impacts on some physiological sorghum characteristics.

Keywords: Wheat, physiological parameters, gibberellic acid, UV-C radiation, hydro-priming.

INTRODUCTION

Seed priming has considered a pre-sowing seed treatment that increases the seed's biochemical and physiological activity and thus stimulates seed performance by improving germination and seedling characteristics in various crops. Priming seeds gibberellic acid and ascorbic acid in have reportedly been a straightforward and safe technique for enhancing germination and development in a variety of agricultural crops (Kumari *et al*., 2017; Shihab and Hamza, 2020; Lazim, 2023). On the other hand, some physical pre-sowing priming techniques, such as magnetic fields, microwaves, laser, and UV radiation, are commonly used successfully to improve the germination of seeds and growing plants (Wang *et al*., 2019; Lazim and Ramadhan, 2020). Compared to these physical techniques pre-sowing seed with exposure to the magnetic field (magneto-priming) is considered eco-friendly due to the technique's demonstrated good impacts on seed germination and relative simplicity, low cost, and increased safety (Joshi-Paneri *et al*., 2023). Previous studies with different plant species reported an improvement in germination characteristics of magnetically treated seed by Martinez *et al*. (2000) in barley, Vashisth and Joshi (2017) in maize, Lazim and Nasur (2017) in sorghum, and Joshi-Paneri *et al*. (2023) in soybean. To our knowledge, not much research has been conducted on the effect of traditional and advanced priming techniques as a comparative study in improving the germination of sorghum seeds. Therefore, the purpose of this study was to show how priming techniques can affect the germination and growth of sorghum seeds, including conventional priming techniques like seed priming with hormonal gibberellic acid (AG3) or ascorbic acid (AsA), as well as advanced priming techniques like magnetic fields.

MATERIALS AND METHODS

Treatments and Experimental Design: The reaction of the germination of sorghum seeds for priming was studied at the University of Basrah's Agriculture College's Department of Agricultural Machinery and Equipment's Laboratory of Experimental Physics by magnetic fields (magneto-priming technique) and soaking seeds with Gibberellic acid and

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ascorbic acid (hormonal- priming technique). Experimental date during the May 2022. The experiment conducted by using a CRD (completely random design) of three replicates, two factors, and 27 treatment permutations (plus a control permutation). Healthy sorghum seeds (30 seeds for each treatment) were soaked separately at 25°C in 100 ppm of Gibberellic acid (GA_3) or in 50 mg L^{-1} of ascorbic acid (AsA) for 24 hours, along with soaking in Distilled Water (DW) as a control for the same period for making a comparison of impacts of seed priming. After pre-soaking treatments, the moisture content of the priming seeds was returned to its previous level of dryness in the open forced air at 25±2°C. Then, Static magnetic fields of 125 mT were applied to the three seed priming treatment groups as per the procedure described by Lazim and Ramadhan (2020) as a magneto-priming technique by placing seeds in a cylindrical plastic sample holder for 1 h (MP_2) and 3 h (MP_3). Non-exposing seeds had taken a control (MP_1). Then, each treatment included ten seeds planted in the size of a 20 cm diameter and 15 cm deep plastic container. From the time of planting to the end of germination, each pot group treatment received roughly 200 ml/pot of water every day.

Data Collection: The plants were growing above the soil level after two days. Therefore, there is a starting point for the germination count. Ten days of continuous measurements and observations were made. The germination counting ended on the tenth day when no more seeds germinated.

Germination and growth rates of seeds: There was a daily tally of how many seeds sprouted. On day 10 after planting, we used the following calculation to determine the final germination rate:

$$FGB\% = \frac{N_g}{N_t} \times 100$$

Ellis and Roberts (1981) developed a formula to determine the Mean Germination Time (MGT) of a seed:

$$MGT = \frac{\sum nD}{\sum n} \text{(Day)}$$

The following equation by Al-Mudaris (1998) was used to determine the Germination Rate Index (GRI):

$GRI = G_1/D_1 + G_2/D_2 + \ldots + G_n/D_n$ (%/day).

The Jones and Sanders (1987) formula was used to get the Coefficient of Velocity of Germination (CVG) as CVG= (N1+...+Nx/N1 T1+...+ Nx Tx) × 100

Germination value = (GV), peak value = (PV), and mean daily germination = (MDG) were calculated using Czabator (1962) modified by Kolotelo *et al*. (2001). Germination energy (GE) is the index of seed germination speed and total, calculated as a product of PV and MDG. PV calculated by dividing total percentage of days in which germination occurred by one hundred. The MDG calculated by dividing final germination capacity of day's number that test was conducted.

RESULTS AND DISCUSSION

Seed magneto-priming treatments dramatically boosted yields, as seen in Table 1 the FGB, MGT, GRI, CVG, MDG, PV, and GV, which occurred by seed priming with magnetic at time exposure 1 h followed by time exposure 3 h compared to non-exposing seeds (control). Where sorghum seeds have exposed to a magnetic field with an exposure period of 1 h produced the highest significant values of FGB (91.70%), GRI (26.07% day^{-1}), CVG (26.27), MDG (7.36 seed day^{-1}), PV (3.93), and GV (30.39) as compared with control; whereas the lowest value had found in MGT at 3.79 days. In general, time exposure 1 and 3 h treatment's recorded germination time was less than the comparable values in the controls; hence, magneto-priming seeds germinated at a higher rate than unprimed seeds. In addition, it has been found time exposure of 1 h for the magnetic field was significantly superior to 3 h exposure in most seed traits except FGB and MDG, which increased by 26.98% in GRI, 25.63% in CVG, 29.27% in PV, and 34.70 in GV, in addition, to lower MGT in days by 30.07% (Table 1). The current study's findings on sorghum seed germination are consistent with those of Florez *et al*. (2019), who found that rice seeds germinated much more quickly after being exposed to 126 mT for 1 hour. Furthermore, Florez *et al*. (2007) found that subjecting maize seedlings to 125 mT of constant magnetic field strength for 60 minutes increased the pace of germination and the proportion of germination. Treating soybean and maize seeds with a static magnetic field of 200 mT for an hour showed improved germination and early growth characteristics, as reported by Kataria *et al*. (2015). Martinez *et al*. (2017) found the same thing with grain seeds, and Carbonell *et al*. (2008) found the same thing with grass seeds. Ercan *et al*. (2022) found that barley seeds germinated less well after being exposed to magnetic fields of varying strengths (20, 42, 125, and 250 mT).

Different theories of biochemical and physiological processes, such as ion channel properties or action of certain

Table 1. Effects of seed magneto-priming duration on the germination traits of sorghum.

Magneto-priming	FGP (%)	MGT (day)	GRI (%/day)	CVG	MDG (seed/day)	PV	GV
MP_1 (Control)	75.60±1.94^b	7.56±0.18^a	10.55±0.50^c	13.43±0.42^c	6.29±0.16^b	1.69±0.09^c	10.76±0.79^c
MP_2	91.70±2.63^a	3.79±0.18^c	26.07±1.78^a	26.27±1.02^a	7.63±0.22^a	3.93±0.23^a	30.39±2.54^a
MP_3	88.33±1.86^a	4.93±0.33^b	20.53±1.44^b	20.91±1.23^b	7.35±0.16^a	3.04±0.23^b	22.56±2.06^b
$L.S.D_{0.05}$	5.39	0.17	1.62	0.75	0.45	0.30	3.49

Note: Values were mean ± standard error. Each column's superscript letter represents a significant difference in mean at P 0.05 level. MP_1, MP_2, and MP_3 equals to the magnetic Pre-sowing seed exposure time = 0 (control), 1, and 3 h, respectively.

enzyme activities in seed magneto-priming, which aids in early germination, have been suggested by several authors. Vashisth and Nagarajan (2010) found that amylase, dehydrogenase, and protease enzymes improve the magnetic seed germination of sunflowers. As well as Kataria *et al.* (2015) have found that hydrolytic enzyme activity were found to be higher enhanced germination in magnetically treated soybean and maize seedlings. The working mechanisms of a magnetically treated seed have remained unknown until now. However, many mechanisms theories have been proposed, such as enzyme activity, ion channel properties and reactive oxygen species (ROS) production. However, the effect of a magnetic field on the structure of cell membranes during the germination and development of seeds and young plants is known as the "seed magneto-priming mechanism." which causes the increasing ion transportation in the ion channels and their ionic current density across the cellular membrane, This thus influences metabolic processes (Iqbal *et al*., 2012). Data presented in Table 2 indicated a significant effect on FGB, MGT, GRI, CVG, MDG, PV, and GV occurred by seed priming of GA_3 followed by AsA in contrast to the placebo effect of using pure water. Moreover, GA3 therapy had recorded the greatest gains compared to the control group, which was 11.75 % for FGB, 52.47% for GRI, 31.82% for CVG, 11.86% for MDG, 45.08% for PV and 64.34% for GV, Additionally, MGT timeframes should be cut by 22.50%.

These results may be in harmony with the work done by Erol and Arslanoglu (2022), who found an enhancement in the germination properties of soaking sorghum with gibberellic acid (GA_3). Ardebili *et al*. (2019) and Arun *et al*. (2020) both found results that were consistent with one another when applied to wheat and cowpea, respectively, Aziz and Peksen (2020) on chickpea, Adhikari and Subedi (2022) on maize, Lazim (2023) on wheat. On the other hand, AsA therapy resulted in statistically significant gains compared to the control group, which was 7.62 % for FGB, 40% for GRI, 28% for CVG, 7.65% for MDG, 41.51% for PV, and 53.90% for GV, Moreover, MGT should be lowered in terms of days by 19.65% (Table 2). These results may be in harmony with those obtained by Wahid *et al*. 2008 on sunflower, Kumari *et al*. (2017) on maize, and Zalama and Fathalla (2020) on onion. Recently, Baig *et al*. (2021) highlighted the usefulness and beneficial effect of hormonal priming by ascorbic acid on growth and germination properties of soaking wheat cultivars. Soaking the seed in a hormone solution, substances like Ascorbic acid, Salicylic acid, and Gibberellic acid is a method known as "hormonal priming." leading that priming increased germination percentage and seed vigor (Mustafa *et al*., 2017). Due to an increase in the rate of water absorption and greater activities of the enzyme -amylase, Wang *et al*. (2016) hypothesised that pre-soaking treatment with GA_3 potentially improve wheat seed viability and early development characteristics. Every increase in these enzyme activities

Table 2. Effects hormonal priming by Gibberellic acid and ascorbic acid on seed traits of sorghum.

Priming Soaking	FGP (%)	MGT (day)	GRI (%/day)	CVG	MDG (seed/day)	PV	GV
DW (Control)	80.00±2.50^{b}	6.31±0.55^{a}	14.56±1.61^{c}	16.84±1.48^{b}	6.66±0.21^{b}	2.24±0.25^{b}	15.23±2.05^{b}
GA_3	89.40±3.48^{a}	4.89±0.57^{c}	22.20±2.84^{a}	22.20±2.08^{a}	7.45±0.29^{a}	3.25±0.38^{a}	25.03±3.62^{a}
AsA	86.10±2.86^{a}	5.07±0.57^{b}	20.39±2.51^{b}	21.56±2.11^{a}	7.17±0.24^{a}	3.17±0.38^{a}	23.44±3.34^{a}
$L.S.D_{0.05}$	5.39	0.17	1.62	0.75	0.45	0.30	3.49

Note: Values were mean ± standard error. Each column's superscript letter represents a significant difference in mean at P 0.05 level. DW: distilled water (Control); GA_3: Hormonal priming by Gibberellic acid (GA_3); AsA: Hormonal priming by ascorbic acid.

Table 3. Comparison of interaction between magneto-priming, hormonal priming by Gibberellic acid and ascorbic acid on seed traits of sorghum.

Priming treatments	FGP (%)	MGT (day)	GRI (%/day)	CVG	MDG (seed/day)	PV	GV
MP_1× DW	71.66	8.23	8.89	12.18	5.97	1.40	8.39
MP_1× GA_3	78.33	7.12	11.58	14.46	6.52	1.90	12.43
MP_1× AsA	76.70	7.32	11.19	13.65	6.38	1.78	11.45
MP_2× DW	83.30	4.47	19.74	22.31	6.94	3.13	21.82
MP_2× GA_3	98.33	3.33	30.90	28.50	8.19	4.33	35.54
MP_2× AsA	93.30	3.57	27.55	27.99	7.77	4.33	33.81
MP_3 DW	85.00	6.22	15.04	16.04	7.08	2.18	15.49
MP_3× GA_3	91.70	4.22	24.12	23.63	7.63	3.53	27.13
MP_3× AsA	88.33	4.33	22.14	23.05	7.36	3.40	25.05
$L.S.D_{0.05}$	N.S	0.30	2.80	1.29	N.S	N.S	N.S

MP1, MP2, and MP3 equals to the magnetic Pre-sowing seed exposure time = 0 (control), 1, and 3 h, respectively. DW, GA_3, and AsA equals to the distilled water (Control), hormonal priming by Gibberellic acid, and hormonal priming by ascorbic acid, respectively. Each column's superscript letter represents a statistically significant difference in mean at the P 0.05 level. N.S=Non-significance.

causes the seedling's early growth to accelerate. Enzyme stimulation via may be an advantage of ascorbic acid priming, though increases in the activity of peroxidase and polyphenol oxidases leading to an increased respiration rate that improved the germination traits (Hozayn and Ahmed, 2019). The combination effect between magneto-priming and hormonal soaking priming on seed traits of sorghum had provided in Tables 3. Concerning the interaction, results showed that seed priming interactions had significantly enhanced MGT-fighting capabilities of the seed crop with increasing GRI and CVG compared to the unprimed seeds. Significant higher GRI (30.90 % day^{-1}) and CVG (28.50) had reported in combination with magnetic seed for time exposure for 1 h and GA_3 treatments ($MP_2 \times GA_3$), while the significantly lowest effect in MGT (3.33 days) has found. Furthermore, the interaction between priming treatments showed no significant effect on FGB, MDG, PV, and GV (Table 3). However, the $MP_2 \times GA_3$ combination had a higher FGB (98.33 %), MDG (8.19 seed day^{-1}), PV (4.33), and GV (35.54). The best values for germination percentage, seedling growth, and seedling vigour characters were recorded by Patel *et al.*, 2018 in the priming of maize seed with a static magnetic field and Gibberellic acid.

Similar improvements in the magneto-priming and AsA combination effects in seed vigor traits of onion had recorded by Zalama and Fathalla (2020). The improvements in sorghum seed germination traits may be mainly due to the increases conferred by the combinations of magneto-priming with GA_3 or AsA treatments. No other research that I am aware of has used magnetic fields in conjunction with seed priming (magneto-priming) and hormonal priming seed with gibberellic acid or ascorbic acid in terms of their presowing sorghum's seed viability and seedling development. That means my findings can't be compared to anyone else's.

***Conclusion*:** In conclusion, this study shows that seed priming treatments magneto and hormonal significantly affected the sorghum germination development traits, including FGB, MGT, GRI, SL, RL, and SVI. Significant higher GRI and CVG were reported in a combination priming of magnetic seed for time exposure for 1 h and hormonal GA_3 ($MP_2 \times GA_3$), while the significantly lowest effect in MGT trait has been found. Thus, based on the findings, treating seeds with combinations of 1 h and GA_3 may be promising and useful tools due to their positive effects on some physiological parameters of sorghum seeds.

a combination of hydropriming and microwave

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***Availability of data and material*:** I declare that the submitted manuscript is our work, which has not been published before and is not currently being considered for publication elsewhere?

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